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Richard G. Snyder

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THE SEAT BELT AS A CAUSE OF INJURY

RICHARD G. SNYDER*

The purpose of the automotive seat belt is to provide protection to the occupant by restraining him during an accident. There is substantial evidence to show that the risk of major or fatal injury is considerably reduced when the vehicle occupant is wearing a seat belt during an accident. Reports concluding that regular seat belt usage could reduce serious and fatal injury by 35% to 90% are based upon accident investigation data from many sources.¹ Studies comparing occupant injuries with and without seat belts have clearly shown that in similar accidents unbelted occupants are injured with significantly greater frequency and severity than belted occupants.² The seat belt, properly installed *and properly worn*, still offers the single best protection available to the automotive occupant exposed to an impact.

Nevertheless, experimental tests with animals³ or human volun-

* B.A., M.D., Ph.D., University of Arizona. Head of the Biomedical Department, Highway Safety Research Institute, University of Michigan. Doctor Snyder is a member of many professional societies, including the American Association For Advancement of Science and the American Anthropological Association. He has held research and faculty academic appointments at several major universities. Present research activities include work under sponsorship of the Air Force and the National Highway Safety Bureau. He is the author of more than 100 scholarly papers on restraint systems, impact injury research and aviation and automotive safety. His work in safety and human tolerance to impact forces is internationally recognized.

¹ Tourin & Garrett, *Safety Belt Effectiveness in Rural California Automotive Accidents*, Automotive Crash Injury Research, Cornell Univ. (1970); Kihlberg, *Efficiency of Seat Belts in Injury and Non-injury Crashes in Rural Utah*, Report VJ-27721-R3, Cornell Aeronautical Lab., Inc.; Kihlberg & Robinson, *Seat Belt Use and Injury Patterns in Automobile Accidents*, Report VJ-1823-R30, Automotive Crash Injury Research, Cornell Univ. (1967); Huelke & Gikas, *Causes of Death in Automobile Accidents*, Final Report ORA Project 06749, Univ. of Michigan (1966); Herbert, *Injury Reduction by Diagonal and Other Vehicle Safety Belts*, 1 MED. J. OF AUSTRALIA 61 (1964); Backstrom, *Traffic Injuries in South Sweden With Special Reference to Medico-Legal Autopsies of Car Occupants and Value of Safety Belts*, ACTA CHIRURGICA SCANDINAVICA, SUPP. 308 (1963); Lister & Milsom, *Car Seat Belts: An Analysis of the Injuries Sustained By Car Occupants*, 191 PRACTITIONER 332 (1963); Lingren & Warg, *Seat Belts and Accident Prevention*, 188 PRACTITIONER 467 (1962); Schwimmer & Wolf, *Leading Causes of Injury in Automobile Accidents*, Automotive Crash Injury Research, Cornell Univ. (1962).

² See Huelke, page 202 *supra*; Huelke & Chewning, *Comparison of Occupant Injuries With and Without Seat Belts*, Society of Automotive Engineers, Inc., Paper No. 690244 (1969); Siegel, Van Wagoner & Nahum, *Case Comparisons of Restrained and Non-restrained Occupants and Related Injury Patterns*, Society of Automotive Engineers, Inc., Paper No. 690245 (1969).

³ De Haven & Macri, *Aircraft Safety Belts: Their Injury Effect on The Human Body*, Crash Injury Research, Cornell Univ. Med. College (1953); Campbell, *Role of the Safety Belt in Nineteen Auto Crashes*, 40 AMERICAN COLLEGE OF SURGEONS 155 (1955); *Auto Seat Harnesses*, CONSUMER REPORTS 484 (October 1962); Snyder, Young & Snow, *Experimental Impact Protection With Advanced Automotive Restraint Systems*, Proceedings, 11th Stapp Car Crash Conference (1967); States, *Case Studies of Racing Accidents*, Proceedings,

teers,⁴ as well as clinical evidence from accident studies,⁵ have indicated

8th Stapp Car Crash Conference 251 (1964); States & Ryon, *Restraint Systems in Racing Accidents*, Society of Automotive Engineers, Paper No. 690246 (January 1969).

⁴ Snyder *et al.*, *Pathology of Trauma Attributed to Restraint Systems in Crash Impacts*, 39 AEROSPACE MEDICINE 812 (1968); Bohlin, *A Statistical Analysis of 28,000 Accident Cases with Emphasis on Occupant Restraint Value*, Proceedings, 11th Stapp Car Crash Conference 299 (1967); Wexler & Silverman, *Traumatic Rupture of the Innominate Artery: A Seat Belt Injury*, 282 NEW ENG. J. OF MED. 1186 (1970).

⁵ See studies cited at notes 1 and 2 *supra*. See also, Hobson-Walker, *The Value of Safety Belts: A Review*, 102 C.M.A.J. 391 (1970); Snyder, *A Survey of Automotive Occupant Restraint Systems*, Society of Automotive Engineers Paper No. 690243 (January 1969); Roberts, *Motor Vehicle Restraints*, Society of Automotive Engineers Paper No. 700418 (May 1970); Aldman, *European Views on Interior Safety*, Society of Automotive Engineers Paper No. 700419 (May 1970); Snyder *et al.*, *Seat Belt Injuries in Impact, The Prevention of Highway Injury 188*, Highway Safety Research Institute, Univ. of Michigan, (1917); Schneider *et al.*, *Lap Seat Belt Injuries*, 67 MICHIGAN MEDICINE 171 (1968); Seitter & Sharp, *Seat Belt Injuries*, 135 MILITARY MEDICINE 215 (1970); Jolley & Wright, *A Study of Several Vehicular Accidents*, Final Report, Project B-605, Georgia Institute of Technology; Teare, *Post-Mortem Examination on Air Crash Victims*, 2 BRITISH MED. J. 707 (1951); DuBois, *Safety Belts Are Not Dangerous*, 2 BRITISH MED. J. 605 (1952); Hasbrook, *Severity of Injury In Light Plane Accidents*, Aviation Crash Injury Research, Flight Safety Foundation, Report AvCir 6-ss-105 (July 1959); Garrett & Braunstein, *The Seat Belt Syndrome*, 2 J. OF TRAUMA 220 (1962); Fish & Wright, *The Seat Belt Syndrome—Does It Exist?*, 5 J. OF TRAUMA 746 (1965); Sube, Zipperman & McIver, *Seat Belt Trauma To The Abdomen*, 113 AMERICAN J. OF SURGERY 346 (1967); Jowland, Curry & Buffington, *Fulcrum Fractures of the Lumbar Spine*, 193 J.A.M.A. 240 (1965); Fletcher & Bragdon, *Seat-Belt Fractures of the Spine and Sternum*, 200 J.A.M.A. 177 (1967); Smith & Kaufer, *A New Pattern of Spine Injuries Associated With Lap Type Seat Belts*, 33 U. OF MICH. MED. CENTER J. (1967); Schneider *et al.*, *"Hangman's Fracture" of the Cervical Spine*, 22 J. OF NEUROSURGERY 141 (1965); Aiken, *Intestinal Perforation and Facial Fractures in an Automobile Accident Victim Wearing a Seat Belt*, 115 J. LA. STATE MED. SOCIETY 235 (1963); Tolins, *An Unusual Injury Due to the Seat Belt*, 4 J. OF TRAUMA 397 (1964); Kulowski & Rost, *Intra-Abdominal Injury from Safety Belt in Auto Accident*, 73 ARCHIVES OF SURGERY 970 (1956); Campbell, *Seat Belts and Abdominal Surgery*, 75 ARCHIVES OF SURGERY 150 (1967); Gerritsen, Froese & Pezzi, *Unusual Abdominal Injuries Due to Seat Belts*, 14 J. OF ALBERT EINSTEIN MED. CENTER 63 (1966); Cooke & Meyer, *Splenic Rupture Due to Improper Placement of Automotive Safety Belt*, 183 J.A.M.A. 693 (1963); Porter & Green, *Seat Belt Injuries*, 96 ARCHIVES OF SURGERY 242 (1968); Williams, Lies & Hale, *Intra-Abdominal Injuries from Seat Belts*, 6 J. OF TRAUMA 303 (1966); Brunius & Lindgren, *The Effectiveness of Safety Belts*, 66 NORDIC MEDICINE 1500 (1961); Gikas & Huelke, *Causes of Death In Automobile Accidents—Can Seat Belts Really Save Lives?*, 63 J. OF MICH. STATE MED. SOCIETY 351 (1964); Birrell, *Safety Belts For Motor Vehicles in Victoria*, 1 MED. J. OF AUSTRALIA 67 (1964); States, *Improved Upper Torso Restraint System*, 282 NEW ENG. J. OF MED. 1206 (1970); Stapp, *Tolerance to Abrupt Deceleration*, Collected Papers on Aviation Medicine 122 (1955); Beeding & Stapp, *Daisy Track Tests 133-155*, Air Force Missile Development Center, Holloman Air Force Base Test Report No. 6 (1957); Taylor, Rhein & Beers, *Effects of Atropine Upon the Relative Bradycardia Associated With Impact*, Holloman Air Force Base Technical Report No. ARL-TDR-62.13 (1962); Fisher, *Injury Produced By Seat Belts*, 2 J. OF OCCUPATIONAL MED. 211 (1965); Ebbetts, *Seat Belts and Cervical Spondylosis*, 188 PRACTITIONER 802 (1962); Hamilton, *Seat Belt Injuries*, 4 BRITISH MED. J. 485 (1968); Carroll & Gruber, *Seat Belt Fractures*, 91 RADIOLOGY 517 (1968); von Bahr & Erikson, *Injuries Caused by Seat Belts*, 58 SVENSKA LAKARTIDNINGEN 141 (1961); Engberg, *Injuries Caused by Safety Belts*, 58 SVENSKA LAKARTIDNINGEN 884 (1961); Bastiaanse & Bouwman, *Statistical*

that this protective device may itself contribute to injury in specific circumstances. It must be emphasized that seat belts have never been shown to worsen injury, and while themselves producing injuries, they have prevented more serious ones.⁶ Reviews of the state of the art of seat belts have made,⁷ as well as reviews of seat belt injuries.⁸ As increasing numbers of automotive vehicles provide restraint systems for occupants' use and total accident experience of belt wearers increases, some injuries have been attributed directly to the belt itself. Such reports are relatively few and are scattered throughout the medical literature, in general consisting of clinical accounts of only a few cases. Until January, 1968, installation of type II restraints (consisting of both a lap belt and upper torso belt) was not required on production cars manufactured in the United States. Thus, most injuries reported in the literature involve experience with the lap-type seat belt only. Very few cases have been reported to date involving upper torso restraint systems. In such a system, the lap belt is in contact with the lower abdominal area of the body, while the upper torso restraint contacts the thorax and shoulder area. Therefore, different patterns of injury have been observed with this type of belt as compared to the more familiar lap belt.

REVIEW OF THE MEDICAL LITERATURE

LAP BELT RESTRAINT

Earliest reports of injuries attributed to seat belts are found in aircraft accident studies. In a 1951 jet airliner crash in England, abdominal and thoracic aortic ruptures were reported to have resulted from the snubbing action of the lap belt, with forced flexion of the torso.⁹ A study of individuals involved in serious aircraft accidents while wearing lap belts indicated 23 cases of intra-abdominal injuries and 32 cases of contusions along the belt line.¹⁰ Such contusions, occurring as the belt impinges on the body, are the most common form of lap belt injury, but usually are of minor significance. In an investigation of injuries sustained by 1,039 survivors of 670 light aircraft crashes, no significant effect due to severe snubbing action of the belt was found, except for bruises and minor contusions.¹¹

Study: Effectiveness of Seat Belts, RAPPORT RAI-TNO, INSTITUT VOOR WEGTRANSPORT MIDDELEN (Netherlands) (1966); Saldeen, *Fatal Neck Injuries Caused By Diagonal Safety Belts*, 7 J. OF TRAUMA 856 (1967); Gilbeau & Turner, *The Effect of Travel on Interruption of Pregnancy*, 66 AMERICAN J. OF OBST. & GYN. 1224 (1953).

⁶ Hobson-Walker, note 5 *supra*.

⁷ Snyder, note 5 *supra*; Roberts, note 5 *supra*; Aldman, note 5 *supra*.

⁸ Hobson-Walker, note 5 *supra*; Snyder *et al.*, note 5 *supra*; Schneider *et al.*, *Lap Seat Belt Injuries*, note 5 *supra*; Seitter & Sharp, note 5, *supra*; Jolley & Wright, note 5 *supra*.

⁹ Teare, note 5 *supra*.

¹⁰ DuBois, note 5 *supra*.

¹¹ De Haven, Tourin & Macri, note 3 *supra*.

These conclusions were confirmed in a subsequent analysis of 1,965 individuals involved in 913 light aircraft accidents.¹²

Lap belt injuries in automotive accidents have generally been found to involve intra-abdominal trauma, injury to the pelvis, injury to the lumbar spine or external contusions. An analysis of reports of 944 occupants injured while wearing seat belts in automotive accidents showed that 26 of 150 serious lower torso injuries might be attributable to the belt.¹³ It was found that: (1) Seven occupants had possible intra-abdominal injuries, including one with a ruptured pancreas and duodenum and another with a contused bladder and kidney; four of these had abdominal wall contusions from the seat belt. (2) Seven occupants had pelvic injuries, of which six were moderate to severe fractures; of these, two also had abdominal wall contusions from the lap seat belt. (3) Twelve occupants had lumbar spine injuries, of which eight were serious; one of these had abdominal wall contusions due to the snubbing action of the belt. (4) Lumbar muscle sprains or strains were observed in 47 cases. (5) Contusions or soreness over the iliac crests, without apparent internal or skeletal injury, were found in 77 cases. However, the suggestion that a "Seat Belt Syndrome" exists¹⁴ has been disputed.¹⁵

Fractures to the lumbar vertebrae may occur as the individual jackknifes over the lap belt. Eight cases of compression fractures are reported in one study;¹⁶ others have been reported, generally to lumbar vertebrae.¹⁷ A horizontal fracture of the vertebral body, spine and transverse processes may also occur.¹⁸ A unique case of a transverse fracture of a vertebral body, which occurred in a 19 year old youth who ran into a steel pole head-on at an estimated speed of 80 mph, has been reported.¹⁹ This fracture, discovered one month after the accident, was attributed to high placement of the seat belt, allowing the belt to act as a fulcrum, literally splitting apart the vertebral body, "similar to breaking a stick over one's knee." A second case has been reported in which a "splitting" fracture of the pedicles, transverse processes, and lamina of the third lumbar vertebrae occurred. The occupant was a loosely lap-belted 21 year old female who struck a semi trailer truck in a sports car at a high rate of speed.²⁰ Similar fractures have been caused by a tension type mechanism described in 10 reported and 12 un-

¹² Hasbrook, note 5 *supra*.

¹³ Garrett & Braunstein, note 5 *supra*.

¹⁴ *Id.*

¹⁵ Fish & Wright, note 5 *supra*; Sube, Zipperman & McIver, note 5 *supra*.

¹⁶ Garrett & Braunstein, note 5 *supra*.

¹⁷ Jolley & Wright, note 5 *supra*; Sube, Zipperman & McIver, note 5 *supra*; Carroll & Gruber, note 5 *supra*.

¹⁸ Hobson-Walker, note 5 *supra*; Fletcher & Bragdon, note 5 *supra*.

¹⁹ Howland, Curry & Buffington, note 5 *supra*.

²⁰ Fletcher & Bragdon, note 5 *supra*.

reported medical cases.²¹ These fractures are usually located between the first and third lumbar vertebrae and involve disruption and longitudinal separation of the posterior elements of the lumbar spine with no compression or forward or lateral movement. They are described as usually accompanied by a visible seat-belt contusion.

An injury of the cervical spine in which the vehicle driver impacts his chin on the steering wheel rim, causing acute flexion of the neck, has been described as the "hangman's fracture." This injury has been attributed to the driver jackknifing over the lap belt. Eight cases in which the drivers sustained a fracture-dislocation of the second and third cervical vertebrae have been reported.²²

Intra-abdominal injuries which have been reported in the literature include rupture of great vessels, perforation of the small bowel, rupture of the spleen, duodenum, and pancreas, tearing of the bowel mesentery, rupture of the gravid uterus and rupture of the urinary bladder. Less serious injuries, such as contusion of the small bowel, kidney, and bladder and the delayed formation of adhesions, are other intra-abdominal injuries which have been described in the literature.

It is not unusual for the discovery of such injuries to be delayed for some time after the impact. In one case a jejunal perforation of the small intestine went undetected until the sixth day after the accident. The attending physician concluded that the injury mechanism was sudden compression of the intestine between the seat belt buckle and the vertebral column. The only external indication of seat belt impingement was a "welt" across the lower abdomen, below the umbilicus.²³ A severe mid-abdominal wall contusion and a perforation of the upper jejunum to a man wearing a lap belt when his car crashed into a tree have been reported; a case of ruptured sigmoid colon has also been described.²⁴ Intra-abdominal injury occurred to a front-seat passenger who claimed to be wearing a "snug" lap belt when her Volkswagen was struck by an oncoming car. There were numerous contusions and faintly visible marks from the lap belt on the lower abdomen and anterior superior spines. Twelve hours later, surgery revealed a tear of the jejunum about eight inches below the ligament of Treitz, which nearly severed the bowel. The accident occurred at the point where the head of the mass of food had progressed at the time of impact. Rupture of the bladder attributed to the lap seat belt occurred in a 16 year old girl who had been drinking beer prior to the accident.²⁵

A single case of small bowel obstruction due to a large adhesion of

²¹ Smith & Kaufer, note 5 *supra*.

²² Schneider *et al.*, "Hangman's Fracture" of the Cervical Spine, note 5 *supra*.

²³ Schneider *et al.*, Lap Seat Belt Injuries, note 5 *supra*; Schneider *et al.*, "Hangman's Fracture" of the Cervical Spine, note 5 *supra*.

²⁴ Tolins, note 5 *supra*.

²⁵ Seitter & Sharp, note 5 *supra*.

the terminal ileum to the right iliac crest of the pelvis was reported in 1956; it was proposed that the adhesion was due to injury to the ileum by the lap belt.²⁶ This conclusion was disputed in a subsequent editorial in the same journal in which it was suggested that "inertial localized hemorrhage" was a more likely cause than the seat belt.²⁷

Cases are reported of nearly identical injuries to two lap-belted, obese women passengers involved in a head-on collision. Both women were wearing lap belts loosely fastened. One, in the left rear seat, received a laceration of the jejunum, multiple laceration of the mesenteric attachments of the small bowel, and traumatic amputation of the lower half of the omentum. The other woman, riding in the right seat, received large laceration of the small bowel, laceration of the ileum and cecum, with division of the ileocecal artery and a tear of the serosa of the sigmoid colon. It was theorized that the jerk of the loose belts during impact allowed the lap belt and buckle to go up the abdomen with a shearing force, tearing the "mesentery and bowel along its course, as well as causing contusions of the abdominal wall."²⁸ Other similar cases are reported.²⁹ Splenic injuries as well as perforation of the ileum and mesentery in isolated cases, have also been reported as attributed to lap belt impingement.³⁰

LAP BELT PLUS UPPER TORSO RESTRAINT

There is as yet little information available regarding injuries which have been attributed to the wearing of a lap belt plus upper torso (type II restraint system) seat belt in U.S. vehicles. The primary reason for this is the fact that this system has been used in automobiles of American manufacturers only since 1968, and therefore injury experience is limited in this country. Most studies relating to injury due to this type of seat belt system are from Europe, where such systems have been in use for some years. It has been shown that use of the upper torso plus lap belt system can provide additional protection over the lap belt alone, since the properly worn torso belt is intended to prevent jackknifing forward.³¹ This reduces the hyper-flexion of the body over the lap belt, and prevents the upper body from flexing forward and striking injury-producing structures. While some injuries have been

²⁶ Kulowski & Rost, note 5 *supra*.

²⁷ Campbell, note 5 *supra*.

²⁸ Gerritsen, Froese & Pezzi, note 5 *supra*.

²⁹ LeMire, Earley & Hawley, *Intra-Abdominal Injuries Caused by Automobile Seat Belts*, 201 J.A.M.A. 109 (1967); MacLeod & Nicholson, *Seat Belt Trauma to the Abdomen*, 12 CANADIAN J. OF SURGERY 202 (1969); Campbell, 33 *Fatal Crashes With Seat Belts*, 61 ROCKY MOUNTAIN MED. J. 27 (1964); States & States, *Pathology and Pathogenesis of Injuries Caused by Lateral Impact Accidents*, Proceedings, 12th Stapp Car Crash Conference 82 (1968).

³⁰ Cocke & Myer, 5 *supra*; Porter & Green, note 5 *supra*; Williams, Lies & Hale, note 5 *supra*; Seitter & Sharp, note 5 *supra*.

³¹ Lister & Milsom, note 1 *supra*; Lingren & Warg, note 1 *supra*; Brunius & Lindgren, note 5 *supra*; Gikas & Huelke, note 5 *supra*; Birrell, note 5 *supra*.

attributed to this system, its effectiveness is believed to be significant in preventing what otherwise would be serious injuries and fatalities.

Cases in which an individual is protected from injury in an accident are seldom documented in the literature; one exception is a 1955 study of the role of the lap belt in 19 automotive accidents.³² There are also some isolated case histories.³³ Major evidence for effectiveness of the lap belt plus upper torso restraint is reported in data of accident studies and in experimental investigations involving animal subjects.³⁴ The most extensive study to date, of Swedish accidents, indicated that no fatal injuries were caused by the restraint system in 9,569 accidents. The most serious injuries reported were six cases of multiple rib fractures.³⁵ The first fatal injury in this country, attributed to the lap belt plus diagonal upper torso belt restraint, involved rupture of the innominate artery of a wearer of this system. The injury occurred in a head-on collision of a Swedish sports car.³⁶ Less serious cervical injuries had been previously reported.³⁷ Almost all studies with human volunteers wearing upper torso restraint have involved double upper torso restraints, rather than the single diagonal strap used in present automobiles. Nevertheless, such studies clearly demonstrate that when the upper body is prevented from jackknifing or flexing forward, human tolerance to impact is considerably greater than with the lap belt alone.³⁸

One of the earliest analyses of automotive seat belt injuries was conducted in Sweden. It dealt with 210 accidents between 1957-1960 in which belts were worn. With the exception of one belt breaking, one individual slipping out of his belt and being thrown from the car, and a third case in which the belt was too loose, the report indicated no internal injuries or aggravation of injuries due to the combination lap belt-upper torso belt system.³⁹ In England, data on 600 accidents involving 837 belted front seat occupants compared injuries occurring with different types of belts. The four types considered were full harness, lap and diagonal pillar fitting (3 point), lap, and diagonal only. The study found an overall reduction of expected injuries, in

³² Campbell, note 30 *supra*.

³³ Snyder *et al.*, *Seat Belt Injuries in Impact*, note 5 *supra*.

³⁴ Snyder *et al.*, *Seat Belt Injuries in Impact*, note 5 *supra*; Snyder *et al.*, note 4 *supra*; Snyder *et al.*, note 3, *supra*; Snyder *et al.*, *Impact Injury to the Pregnant Female and Fetus in Lap Belt Restraint*, Proceedings, 10th Stapp Car Crash Conference (1967); Crosby *et al.*, *Impact Injuries in Pregnancy*, 101, AMERICAN J. OF OBSTETRICS 100 (1968); Van Kirk & King, *A Preliminary Study of an Effective Restraint System for Pregnant Women and Children*, Proceedings, 13th Stapp Car Crash Conference 353 (1969).

³⁵ Bolin, note 4 *supra*.

³⁶ Wexler & Silverman, note 4 *supra*.

³⁷ States, *Improved Upper Torso Restrain System*, note 5 *supra*.

³⁸ Stapp, note 5 *supra*; Beeding & Stapp, note 5 *supra*; Taylor, Rhein & Beers, note 5, *supra*.

³⁹ Brunius & Lindgren, note 5 *supra*.

comparison with accidents in which belts were not worn.⁴⁰ In Australia similar findings were reported.⁴¹

Splenic rupture in a single case from use of a lap belt plus upper torso restraint was first reported in 1965,⁴² and in a second case in 1967.⁴³ One hyper-extension hyper-flexion ("whiplash") injury was attributed to this combination belt system.⁴⁴ A head-on collision occurred where two drivers and two passengers were all wearing combination lap-diagonal shoulder belts. Three of the four individuals received severe abdominal ruptures and two of these had flexion-compression injuries to the vertebra.⁴⁵ However, looseness and improper fit of the belts, which were apparently not original equipment for either automobile, were believed to be important factors influencing the injuries received.

SINGLE DIAGONAL RESTRAINT

In some European automobiles a *single diagonal belt*, with no lap belt, is worn, extending from over one shoulder to the opposite hip. Generally this type of belt is anchored to the car's center pillar or to the roof rail above the rear door, and extends across the occupant's shoulder and chest on the outboard side, angling diagonally across the flank to the floor. A disadvantage of this system is that with no lap belt support across the pelvic area, the body is free to swing forward and rotate out of the belt at impact, unless the body is stopped by striking the interior structure. This system has been shown to be capable of producing fatal injury in animal tests.⁴⁶ It is significant that the warning "This shoulder strap is not to be used without a lap belt" is printed in the Owner's Manual or on the labels of current type II (combined lap belt—upper torso belt) restraints in American produced automobiles.

Tests comparing various seat belt systems indicated that in a severe front-end collision, this type of strap can cause severe injuries to internal organs or the neck (when the wearer slides out of the belt). Even a lap strap alone was considered preferable, since at least it put the pressure on the well-protected pelvic area.⁴⁷ Some accident studies support these conclusions. In one study it was found that the diagonal upper torso belt can produce a more serious injury than the lap belt.⁴⁸ About 80% of the 712 occupants who were injured while wearing seat belts who were considered in a South Sweden study were wearing

⁴⁰ Lister & Milsom, note 1 *supra*.

⁴¹ Birrell, note 5 *supra*.

⁴² Fisher, note 5 *supra*.

⁴³ Fletcher & Bragdon, note 5 *supra*.

⁴⁴ Snyder *et al.*, note 4 *supra*.

⁴⁵ Hamilton, note 5 *supra*.

⁴⁶ Snyder *et al.*, note 4 *supra*.

⁴⁷ *Auto Seat Harnesses*, note 3 *supra*.

⁴⁸ Williams, Lies & Hale, note 5 *supra*.

the diagonal belt. However, the type of belt used was not considered in an analysis of the data. Significantly, of 60 injuries noted (not defined as to whether related to the belt) 44 injuries occurred to occupants wearing the diagonal belt.⁴⁹ Cases of multiple fractures of the ribs, fractured clavicles, fractured sternum, and ruptured liver, and one case of rupture of the left atrium of the heart have been attributed to the diagonal type of belt. One study of 382 accidents compared injuries where different belt systems were used. In reference to side impact occurring to drivers wearing diagonal belts, the question was raised, whether the belt may not accentuate the violence sustained by the driver's pelvis when it is thrown against the door during deceleration.⁵⁰ Four cases, 2 fatal, were reported in Sweden involving diagonal belts causing kidney rupture, rupture of the kidney and spleen⁵¹ and fatal rupture of the vena cava.⁵²

In an earlier study of 210 accidents to car occupants while wearing belts, the pressure of the belt was considered not to have caused any internal injuries.⁵³ One case of a ruptured spleen has been attributed to a diagonal belt.⁵⁴ A study of 900 Dutch accidents compared the effectiveness of lap, three-point, and diagonal restraint systems. Twice as much head injury for lap-belt users as for users of other types was reported. But three times as many chest and leg injuries for diagonal and three-point users as for lap-belt users was found.⁵⁵

Analysis of 712 front-seat-belted occupants in accidents in Sweden showed that chest injuries were relatively common, occurring in 252 cases (14%) and attributed to the steering wheel.⁵⁶

An oblique fracture of the sternum received by a 33-year-old physician has been reported. He struck a tree at about 35 mph in a small Swedish car while wearing a diagonal belt.⁵⁷ Looseness of the belt permitted several inches of forward movement of the thorax, but prevented contact with the steering assembly. It was concluded that this type of belt cannot guarantee safety.⁵⁸ Three cases of partial or complete decapitation have been reported in use of diagonal belts without lap belts. All were side impact accidents involving occupant ejection when the door latches failed. Such severe neck injury has not occurred when lap belts are used in conjunction with the shoulder belt.⁵⁹

⁴⁹ Carroll & Gruber, note 5 *supra*.

⁵⁰ Lingren & Warg, note 1 *supra*.

⁵¹ von Bahr & Erikson, note 5 *supra*.

⁵² Engbert, note 5 *supra*.

⁵³ Brunius & Lindgren, note 5 *supra*.

⁵⁴ Hansen & Rasmussen, note 5 *supra*.

⁵⁵ Bastiaanse & Bouwman, note 5 *supra*.

⁵⁶ Jolley & Wright, note 19 *supra*.

⁵⁷ Fletcher & Bragdon, note 5 *supra*.

⁵⁸ *Id.*

⁵⁹ Saldeen, note 5 *supra*.

DOUBLE SHOULDER RESTRAINT

Few restraint systems consisting of the lap plus double upper torso belt are presently in use in American production vehicles, although they have long been used in aircraft and racing vehicles. An exception is the Shelby American (Cobra) GT-350 and GT-500 automobile, which from late 1966 to 1969, utilized a variation of the double shoulder restraint harness. This system resembles an inverted Y, with a lap belt and double shoulder harness joining into a single belt behind the head which is attached to a roll-bar mounted inertia reel. In an experimental comparison of seat belt injuries, this system proved relatively more effective than either the single lap belt or type II lap belt with single diagonal belt.⁶⁰ Only isolated reports of accidents with this type of seat belt system have been made, and no injuries to date have been published. In one case a racing driver spun through a guard rail at 80 mph and survived the crash without injury. In a second accident the driver was involved in a crash on the Los Angeles Freeway, reportedly at 70 mph, without injury. Many similar accidents may have occurred in which the seat belt protected the occupant from injury; however such cases are rarely reported—only when injuries occur are reports published.

Some studies of racing car accidents in which the driver was wearing a double shoulder type of seat belt have been made.⁶¹ A study by the Road Research Laboratory in England considered 355 individuals wearing full harnesses in accidents; 214 received no injury. Of the 111 receiving some injury, 36 injuries were to the head, 6 to the neck, 17 to the thorax (including belt bruising), 5 to the thigh, and the balance of 47 to the lower extremities. However, information concerning correlation with type of accident and impact conditions was not provided. A similar study conducted in the United States might demonstrate even better protective results, since American vehicles are larger and intruding environments offer more distance between the occupant and environment during an impact. This study indicates that the full-body restraint provides good protection in even severe accidents, compared to other types worn. The authors conclude that this type of harness, in comparison to the other types studied, provided more restraint to the upper torso, resulting in fewer head and neck injuries but more chest injuries, including bruising caused by the seat belt assembly.⁶²

INJURIES TO PREGNANT BELT WEARERS

In the United States most women travel by automobile at one time

⁶⁰ Snyder *et al.*, *Seat Belt Injuries in Impact*, note 5 *supra*; Snyder *et al.*, note 4 *supra*; Snyder *et al.*, note 3 *supra*.

⁶¹ States, note 3 *supra*; States & Ryon, note 3 *supra*.

⁶² Lister & Milsom, note 1 *supra*.

or another during their pregnancy.⁶³ It is estimated that each year thousands of pregnant women are involved in vehicular accidents. Until recently there was practically nothing known about possible seat belt effects upon the pregnant mother and her fetus.⁶⁴ If the lap belt is worn, nearly all frontal collisions will produce folding of the abdomen over the seat belt. In minor accidents this is usually of little consequence. But when the victim is pregnant, there has been concern that the resultant abdominal compression could produce uterine and fetal injury, even though it is generally acknowledged that the fluid environment offers substantial protection against blunt impact. In 1964 a single case was reported of a lap-belted woman in the sixth month of pregnancy who was riding in the front right seat of an automobile traveling 35 mph, when it was struck from the right front by another vehicle. Although the mother survived, a uterine rupture, attributed to flexion over the lap belt, resulted in fetal death.⁶⁵ Two subsequent cases of uterine rupture have been cited but not reported.⁶⁶ Thirty-eight cases of automobile accidents involving lap-belted pregnant occupants and two cases involving a diagonal belt indicated about 70% survival for the fetus.⁶⁷ However, so few injuries of this type have been published to date that these data must be viewed as preliminary.

In the most extensive study to date, injuries received in 68 accidents where the pregnant victim was wearing a seat belt were compared to 373 accidents where lap belts were not used by pregnant occupants. These data clearly indicate that lap belt restraint reduced both the overall incidence and the severity of injuries to the pregnant wearer. In minor collisions, lap belt restraint provides significant protection from injury with fewer fetal deaths occurring among belted mothers than among those not restrained. However, in severe impacts fetal survival was about the same, regardless of seat belt use. Since the leading cause of fetal death is maternal death, there are fewer fetal deaths when the pregnant mother is belted. No indication was found that the lap belt harms the fetus or the placenta directly and it was concluded that pregnant women should be encouraged to wear lap belts.⁶⁸

Experimental test with pregnant primates have been conducted com-

⁶³ Gilbeau & Turner, note 5 *supra*; Webb, *Travel During Pregnancy*, 4 OBSTETRICS & GYNECOLOGY 22 (1954).

⁶⁴ Gaudaen, Letter to Dr. James L. Goddard, HEW, from Society of Automotive Engineers Motor Vehicle Seat Belt Committee re question "Should seat belts be recommended for pregnant women?" (1959).

⁶⁵ Rubovitz, *Traumatic Rupture of the Pregnant Uterus from Seat Belt Injury*, 90 AMERICAN J. OF OBST. & GYN. 828 (1964).

⁶⁶ Fish & Wright, note 5 *supra*.

⁶⁷ Snyder *et al.*, *Seat Belt Injuries in Impact*, note 5 *supra*.

⁶⁸ Crosby & Costiloe, *Impact Injuries in Pregnancy II: The Effect of Lap Belt Restraint in Human Pregnant Victims of Automobile Collisions*, (unpublished manuscript, Department of Gynecology & Obstetrics, University of Oklahoma School of Medicine).

paring data on both lap belt and lap belt plus upper torso diagonal restraint systems.⁶⁹ Use of the latter type of restraint allowed comparison of data in the absence of forward flexion; experimental restraint systems were also utilized.⁷⁰ In these tests, the 20 G impact configuration simulated a head-on collision at 40 miles per hour. In eleven tests with 12 pregnant animals, all of the adults survived; three received injuries, including two placental separations, a subdural hemorrhage and a broad ligament hematoma. None of the fetuses in these experiments survived, although only 3 of the 11 sustained impact injuries. Two received cerebral hemorrhage and one had a depressed skull fracture. It was found that although an increase in uterine pressure during impact may occur (even when the upper torso is restrained from flexing forward) which is 10 times that observed during labor, the gravid uterus is capable of withstanding very high impact pressures of short duration.⁷¹ These experimental findings are similar to those reported in the clinical literature, although very little data have been published to date.

DISCUSSIONS AND CONCLUSIONS

RELATIVE INSIGNIFICANCE OF SEAT BELT INJURIES

The evidence is overwhelming that safety belts are of prime importance in restraining the automobile occupant during a crash impact. They prevent ejection and reduce the chance of contact with interior structures such as the windshield, instrument panel, or steering system. Ejection and contact with interior structures have been identified in accident studies as the major causes of collision injuries and fatalities. Nevertheless, some injuries have been attributed to the seat belts themselves.

The type of injury that may occur will depend somewhat on the type of seat belt involved. Physical factors are also involved, such as the impact direction and velocity, as well as the sex, age, and physique of the occupant. The most important of these physical factors is whether the belt was loosely or improperly worn. The lap belt alone, which can allow forward flexion of the upper body over the belt, has been reported to occasionally cause compression and/or transverse fractures of the lumbar spine, extensive seat belt contusion and ruptures or tearing of abdominal mesenteries and organs. Rarely have such injuries been fatal. In addition, injuries may occur due to the head striking a structure such as the windshield. The single diagonal belt, without lap belt (as is used in some European cars) may produce the most serious and extensive injuries since it can allow the occupant to rotate out of the belt. The type II lap belt combined with a single diagonal strap, when

⁶⁹ Snyder *et al.*, note 34 *supra*; Crosby *et al.*, note 34 *supra*.

⁷⁰ Van Kirk & King, note 34 *supra*.

⁷¹ Brosby & Costiloes, note 68 *supra*; Snyder *et al.*, note 34 *supra*.

properly worn, usually prevents forward flexion of the upper torso. Relatively few injuries have been attributed to this system, which has only been in widespread use in this country since January 1968. However, these may involve rib or shoulder girdle fractures and intra-thoracic trauma. The type II lap belt combined with double upper torso belts, as used in racing vehicles and the 1966-1969 Shelby American, have been successful in preventing injuries during collisions at very high speeds.

It is important to note that documentation of cases where seat belts have successfully prevented serious injury or death are rarely published. Yet seat belt injuries are still infrequent enough to be published as single cases in medical literature.

Clinical reports of injuries attributed to seat belts often are based upon incomplete evidence. The physician usually has little information concerning the circumstances of the accident. He often cannot be sure of the type of belt used; whether it was actually worn; or if worn, how tightly it was fastened and what position it was in at impact. Experimental studies, for example, have indicated that abdominal injuries to the driver produced by impact to the lower rim of the steering wheel may be similar to the type of injury sometimes attributed to a lap belt. Conversely, although visible contusions over the area covered by the lap belt are most characteristic of lap seat belt injuries, injuries have occurred in isolated cases where heavy outer clothing was worn in the absence of such external evidence. Often the clinical report of injuries is unclear not only as to the type of belt worn and accident conditions, but also because the physician attempting to include a discussion of the mechanism causing injury may in many cases have inadequate factual physical information regarding the accident, as well as insufficient professional experimental knowledge or competence upon which his theory may be validly based.

PROTECTIVE ADVANTAGES OF SEAT BELTS

The few cases where seat belts have resulted in injuries are far outweighed by their protective advantages. For example, the worst case usually cited by critics involves a roll-over in a convertible. However, since only 20% of injury-producing accidents involve a roll-over (including both convertible and hardtop models) the belted occupant obviously has as much protection in a convertible as in 80% of the accidents involving a hardtop vehicle.⁷² This conclusion is based upon 1961 statistics; later model vehicles, due to wider tread and lower center of gravity, appear to roll over even less frequently.⁷³

⁷² Garrett & Braunstein, note 5 *supra*.

⁷³ Garrett, A Study of Roll-Over in Rural U.S. Automobile Accidents, Proceedings, 12th Stapp Car Crash Conference 47 (1968).

Seat belt injuries to the abdomen or even to the lumbar spine are characteristically difficult to diagnose and may not be found until complaints are made some time subsequent to the accident. In one case, for example, partial transection of the ileum was not discovered until exploratory surgery was performed on the thirteenth day post-impact.⁷⁴ In another case a hernia attributed to the belt developed seven months later.⁷⁵ Several reports have detailed diagnostic problems.⁷⁶

The seat belt has been shown to reduce injuries in side impact collisions. By keeping the driver in position, it may prevent additional impacts, loss of control, and running off the roadway under difficult conditions.⁷⁷ The only situation in which the seat belt cannot function well is in the rare case of lateral intrusion directly into the occupant space.⁷⁸

Experimental as well as clinical evidence clearly shows that improper or loose wearing of the seat belt has a substantial influence on resulting injuries. In the case of injuries to the pregnant occupant, improper wearing of the belt loose and high over the fundus has been noted in the majority of cases where injuries have been reported. Injuries have been less commonly associated with the seat belt where the lap belt was correctly worn low and snug over the pelvic area. Examination of most clinical cases reported in the literature of seat belt injuries similarly indicates that a loose fit or incorrect wearing of the seat belt has contributed to the resultant injury.⁷⁹

Comparison between belted and non-belted occupants exposed to similar crash environments clearly indicates the significant protection offered the belted occupant.⁸⁰ Data also indicate that both the pregnant vehicle occupant and her fetus are protected from more serious injury by wearing the seat belt.⁸¹ Where injury to the seat-belted occupant is attributed to the belt itself, such injury is almost invariably of a lesser degree than had the occupant not worn a seat belt. The significance of a comparatively minor belt injury must be viewed in proper perspective to the more serious or fatal injuries shown to occur to unrestrained occupants. Automobile accident deaths or serious injury most often involve

⁷⁴ Fish & Wright, note 5 *supra*.

⁷⁵ Hurwih & Silver, *Seat Belt Hernia: A Ventral Hernia Following an Automobile Crash*, 194 J.A.M.A. 829 (1965).

⁷⁶ Williams, Lies & Hale, note 5 *supra*.

⁷⁷ Siegel, Van Wagoner & Nahum, note 5 *supra*.

⁷⁸ States & States, note 29 *supra*.

⁷⁹ Fletcher & Bragdon, note 5 *supra*; Traylor *et al.*, *Abdominal Trauma from Seat Belts*, 35 AMERICAN SURGEON 313 (1969); McRoberts, *Seat Belt Injuries and Legal Aspects*, 34 INDUSTRIAL MEDICINE & SURGERY 866 (1965); Geritsen, Frobese & Pezzi, note 5 *supra*; Blumenberg, *The Seat Belt Syndrome: Sigmoid Colon Perforation*, 65 ANNALS OF SURGERY 637 (1967).

⁸⁰ Huelke & Chewing, note 5 *supra*; Siegel, Van Wagoner & Nahum, note 5 *supra*; Crosby & Costiloe, note 68 *supra*.

⁸¹ Crosby & Costiloe, note 68 *supra*; Snyder *et al.*, note 34 *supra*; Crosby *et al.*, note 34 *supra*.

contact of the head with interior structures including the windshield, steering wheel column, instrument panel or doors.⁸² The properly worn lap seat belt usually can prevent or reduce the likelihood of the head contacting such structures in an impact, and thus prevent a more serious injury.

⁸² Nahum, Siegel & Trachtenberg, Causes of Significant Injuries in Non-fatal Accidents, Proceedings, 10th Stapp Car Crash Conference 295 (1966).

APPENDIX A

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APPENDIX B

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